

Beam Abort System

2016.6.13

21th SuperKEKB Review

Toshihiro Mimashi

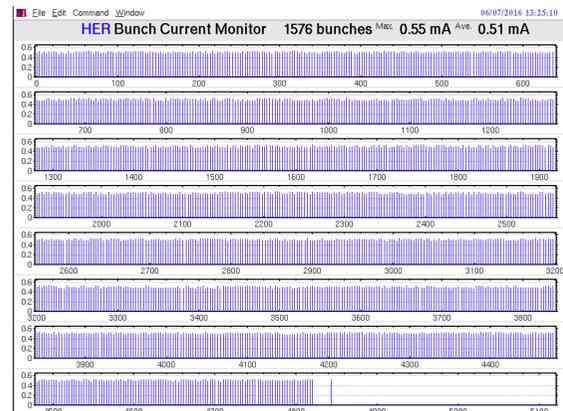
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 - What's going on in the case of failure of kicker magnets

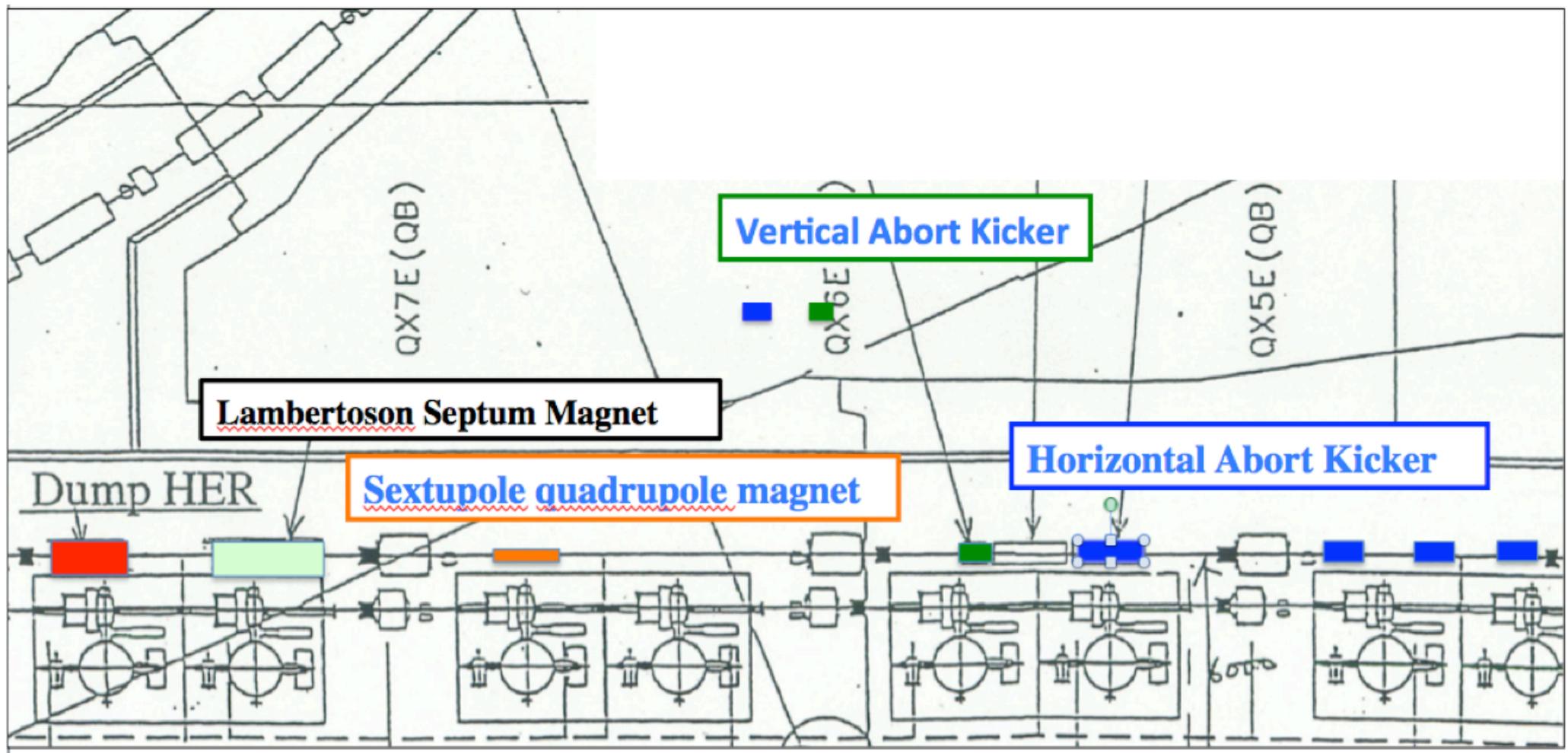
Requirements for The Beam Abort System

- Beam Abort Gap < 200nsec (KEKB abort gap 500nsec)
 - (For Stable operation of RF cavities)
- Enlarge Horizontal Beam size at the extraction window
 - (To protect extraction window)
- Perfect Beam extraction
 - All or Nothing

HER Bunch Current Monitors



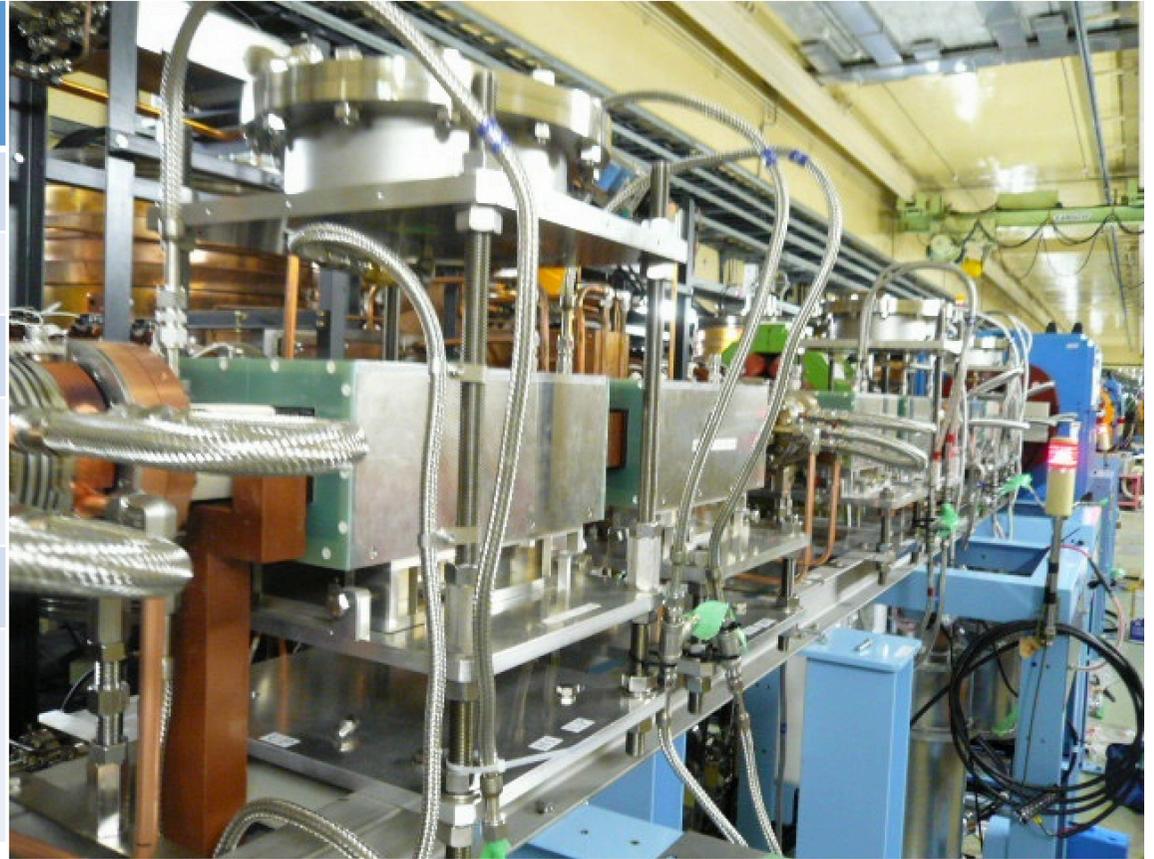
Beam Abort System



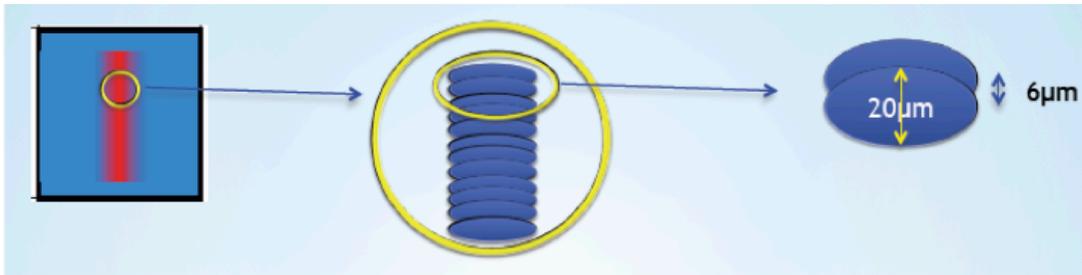
Hardware Components

Abort Kicker Magnets (@7 GeV HER)

Parameters	Horizontal Kicker	Vertical Kicker
θ (mrad)	2.72(Total)	1.38
B(T)	0.02	0.092
I (kA)	1.2	2.1 (3 Turn)
Length of Ferrite	385 x 8	350 x 1
# of coils	4	1
Ceramic Length (mm)	500 x 8	500 x 1

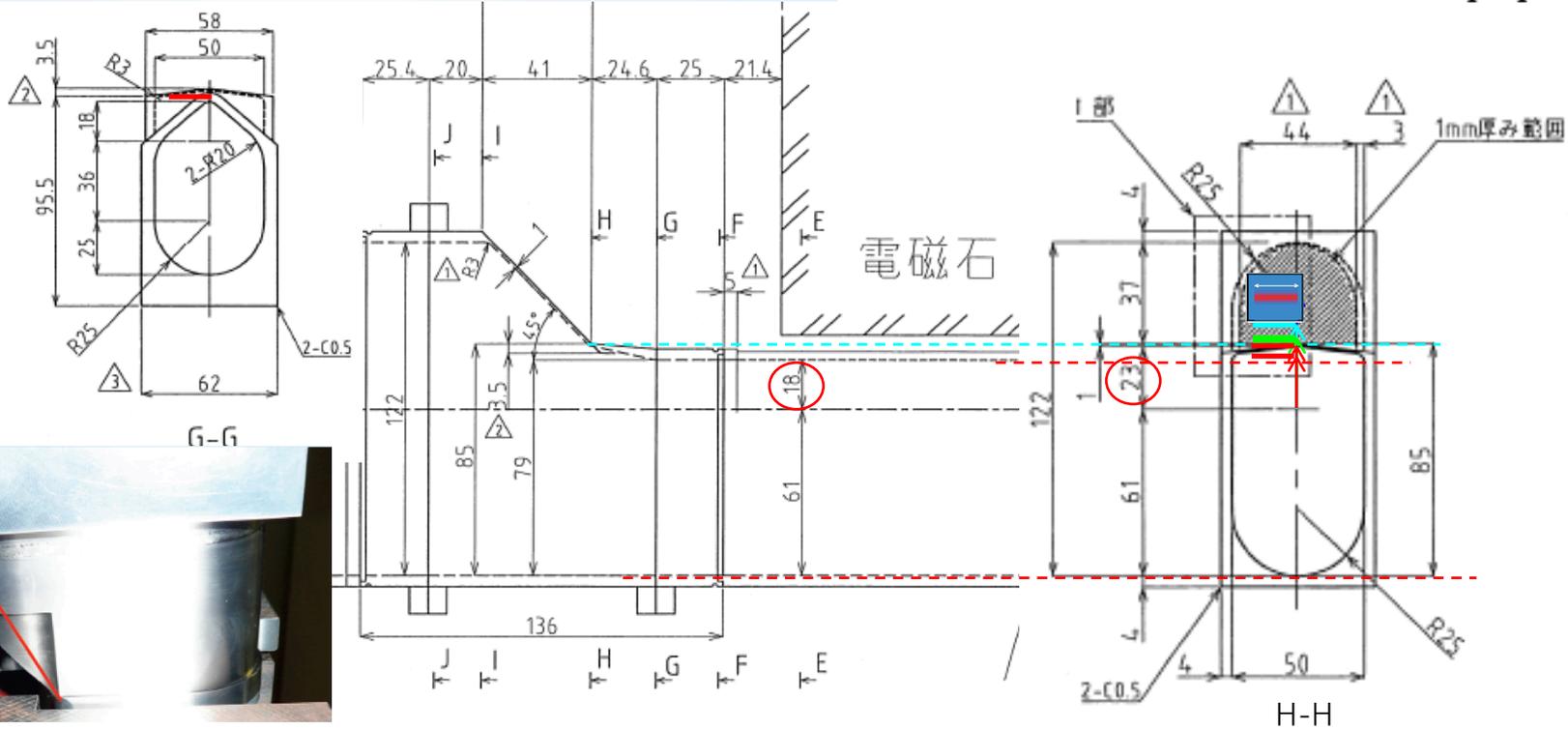


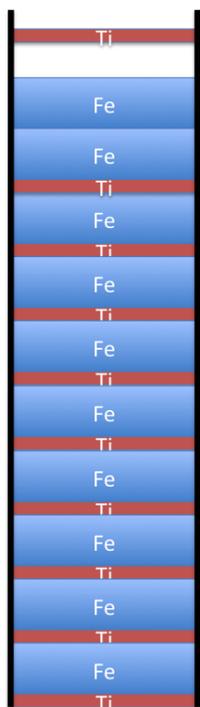
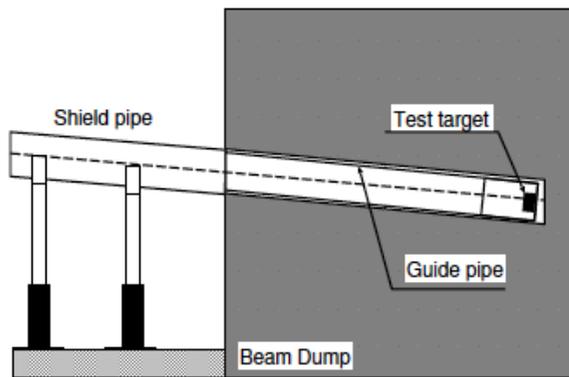
Extraction Window



Z (Atomic Number)	22
A (Mass number)	48
ρ (Density)	4.54 (g/cm ³)
Melting point	1941 K
Boiling Point	3560 K
Phase transition	1153K
Minimum ionization	1.477 MeV/(g/cm ²)
Radiation Length	35.6 (mm)

Table 4 Atomic and nuclear properties of Ti





	KEKB (LER)	SKEKB (HER)
E (GeV)	3.5	7
ϵ_x (nm)	24	4.6
σ_x (mm)@window	0.68	1.1
Vertical Sweep (mm)	10	12-15
I (A)	2	2.6
$I / \sigma_x / \delta Y$ (A/mm ²)	0.3	0.15-0.2

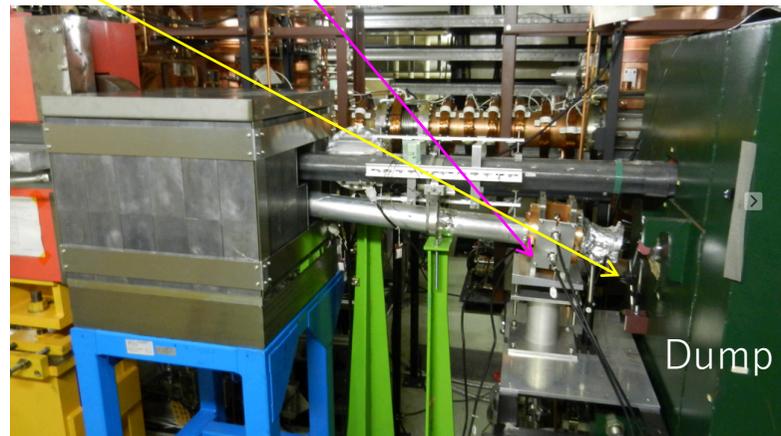
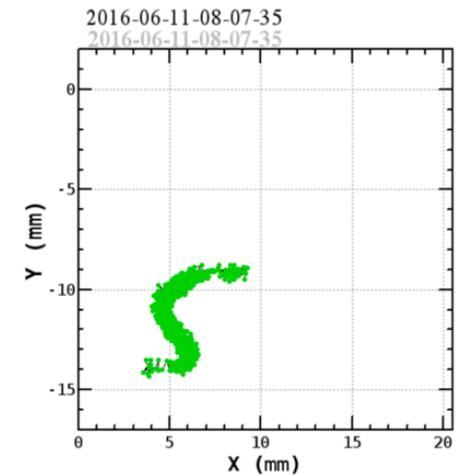
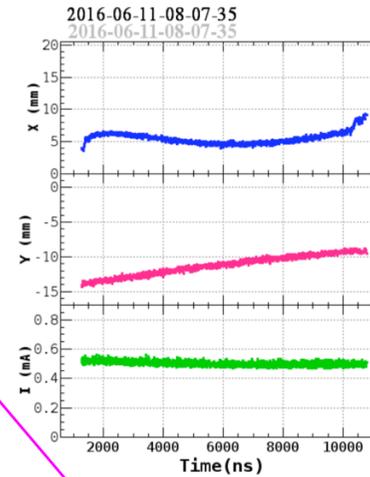
Extraction window Damage Test:
 $I / \sigma_x / \delta Y$ (A/mm²): 0.53 ○ 0.77 ✕



Monitors for the HER extracted beam

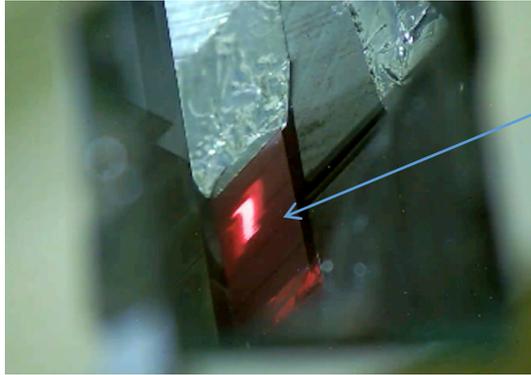
N.lida

- BPM
 1. In front of the dump
- Alumina fluorescent screen
 1. In front of the Lambertson
 2. In front of the dump



Beam profile measurements at the “extraction window”

N. Iida, Y. Enomoto, Y. Suetsugu



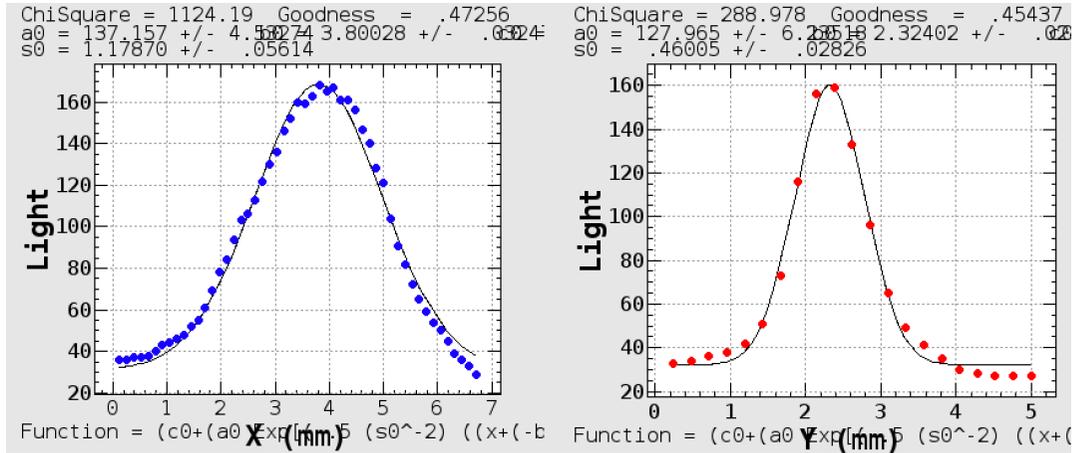
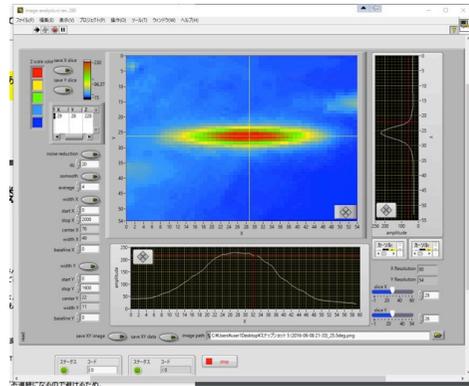
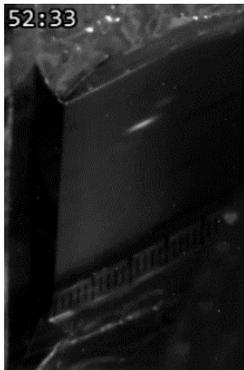
An alumina fluorescent screen ($\Delta t=0.2\text{mm}$), is installed behind the extraction window.
(The extracted beam profile)

2. The horizontal beam size of single bunch is measured.

$$\sigma_x = 1.18 \pm 0.16(\text{mm}) \quad \text{Design: } 1.1(\text{mm})$$

$$\sigma_y = 0.46 \pm 0.13(\text{mm})$$

These are included the multiple scattering at the window and the thickness of the fluorescent screen.

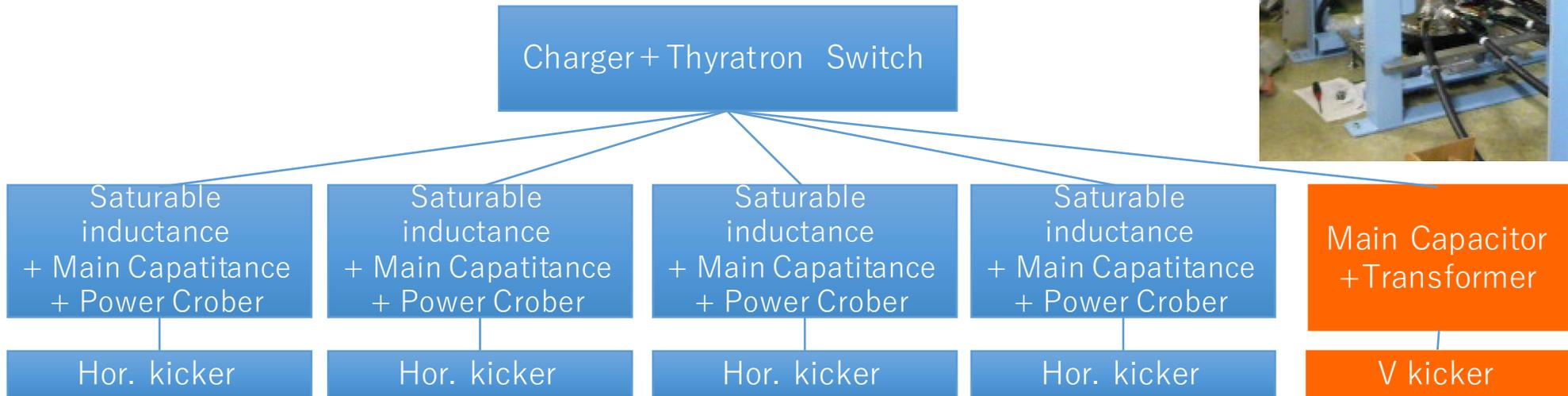


Horizontal beam size

Vertical beam size

Power Supply (HER)

- Common Thyatron switch
- Each Horizontal kicker has main capacitor, saturable inductance and power crowbar diodes.



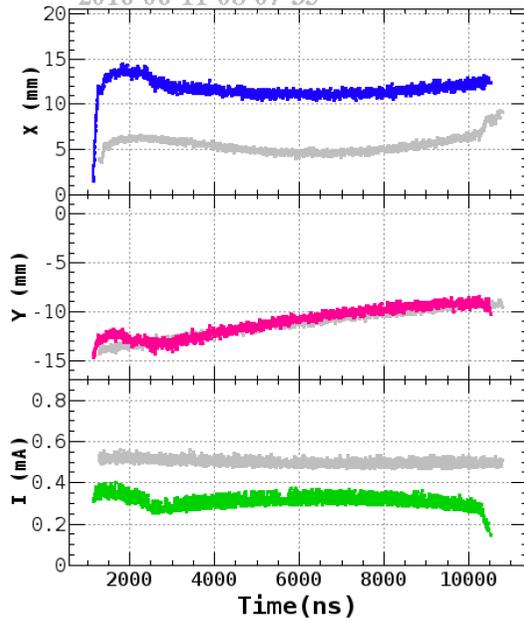
Saturable Inductance



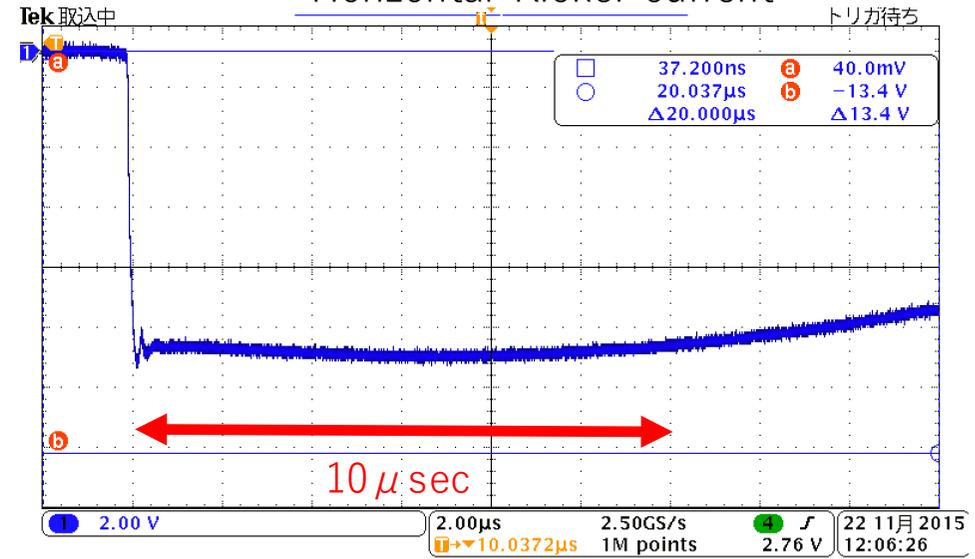
200nsec

Power Crowbar

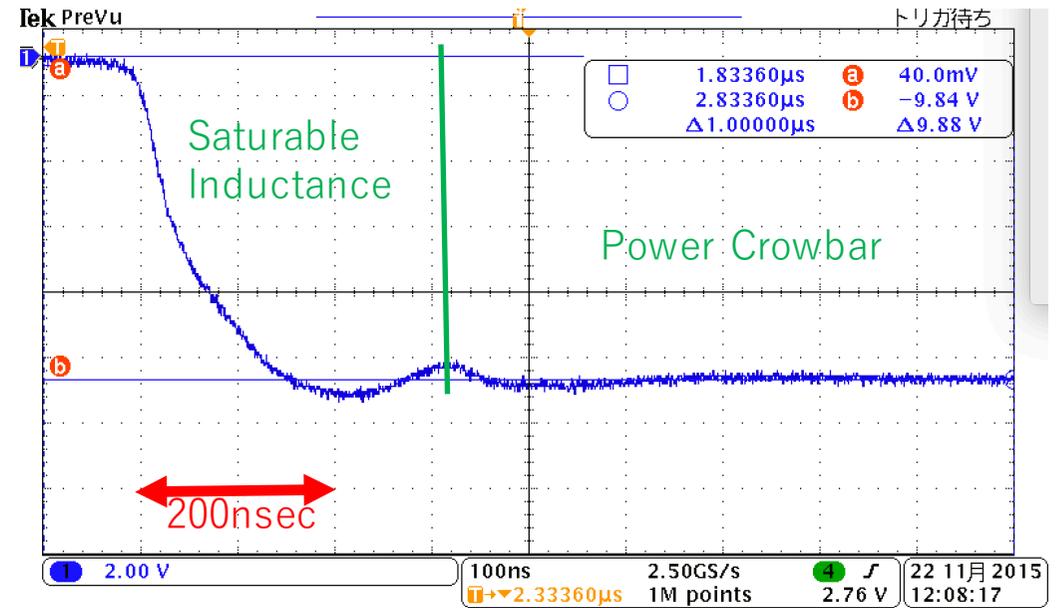
2016-05-26-21-19-14
2016-06-11-08-07-35



Horizontal Kicker current



10 μsec



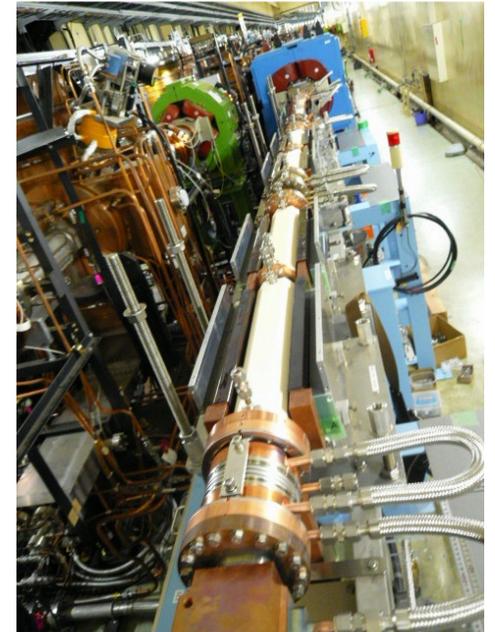
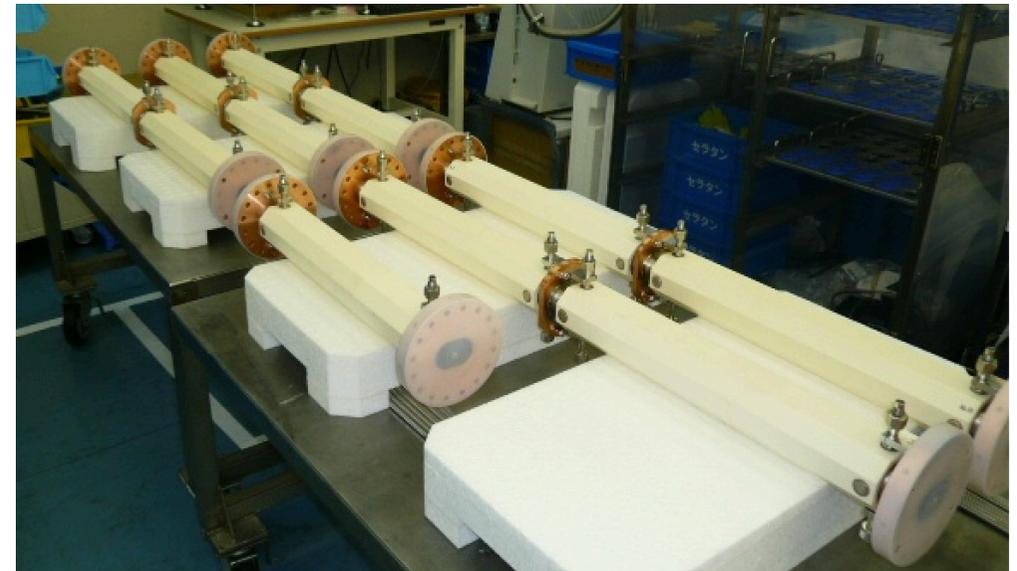
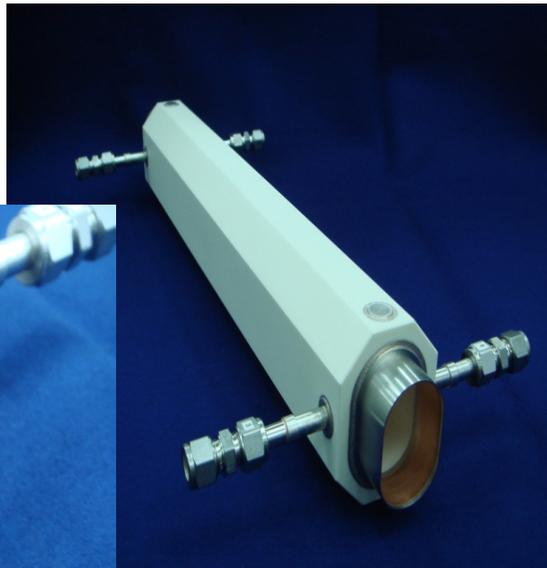
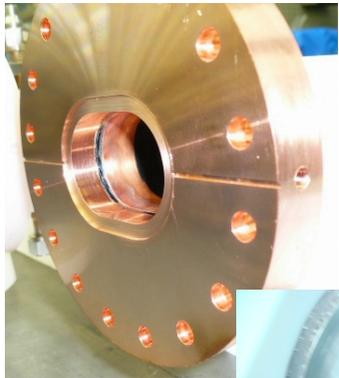
200nsec

Ceramic chamber (Water-cool)

Requirements of Ti-coated ceramic chamber :

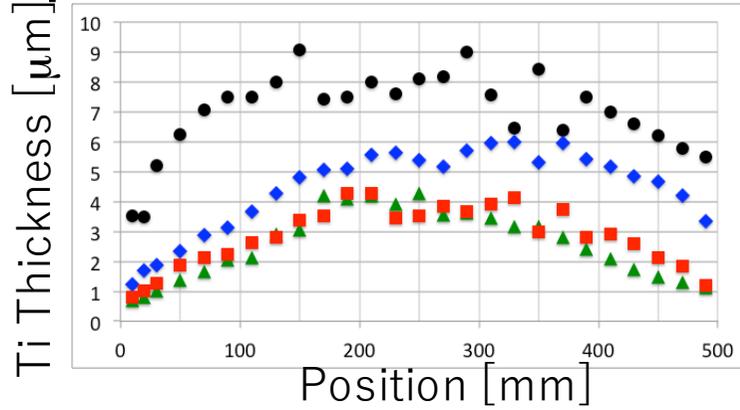
- Penetrate fast kicker magnetic field
- Beam image current passes surface of Ti coating
- Heating on Kovar Sleeve must be small

100 μm Cu Conducting layer coated inner wall of Kovar ($\Delta T < 20^\circ\text{C}@ 2.6\text{A}$)

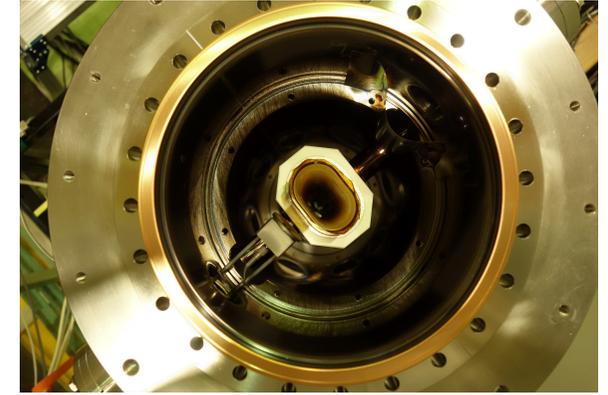
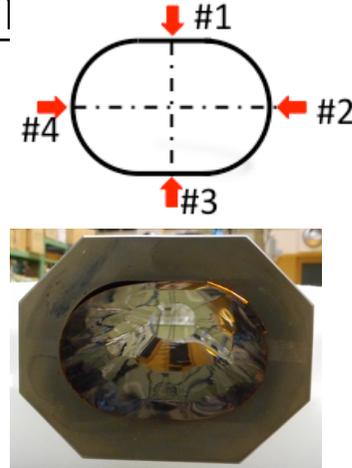


Ti-Thickness Distribution

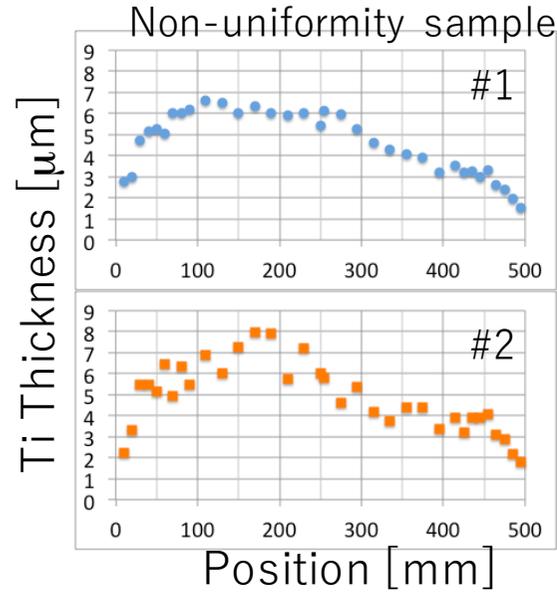
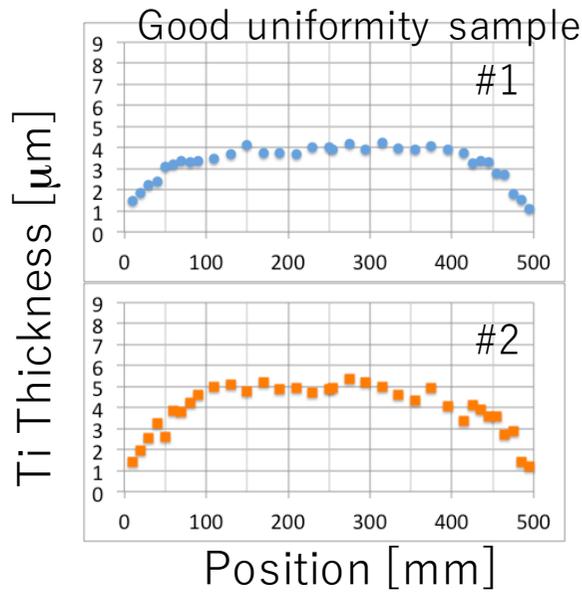
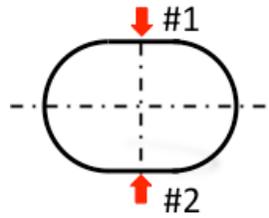
Kapton sheet test



- #1
- ▲ #2
- ◆ #3
- #4

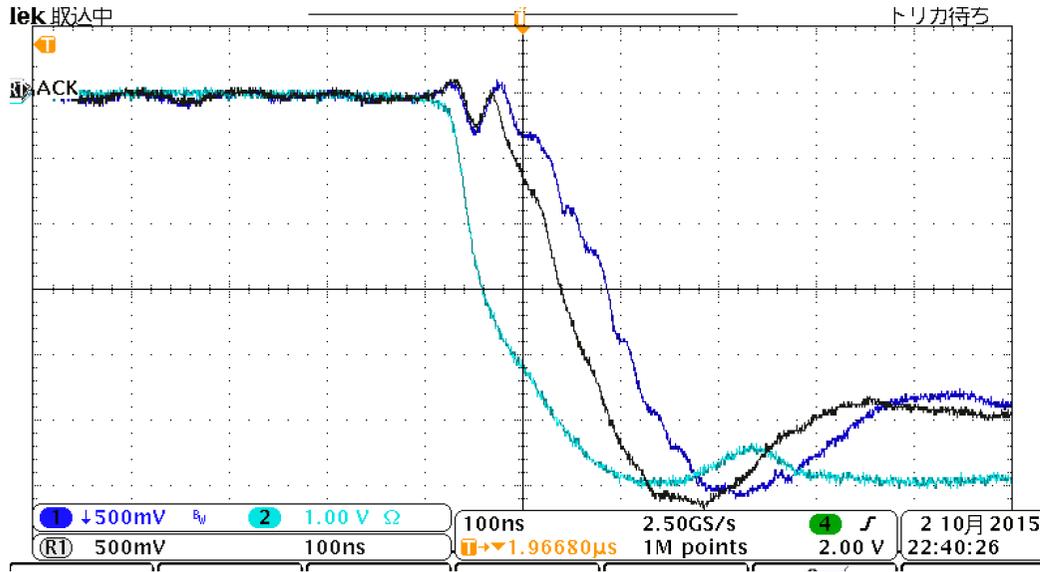


Typical Ti thickness for ceramic chamber



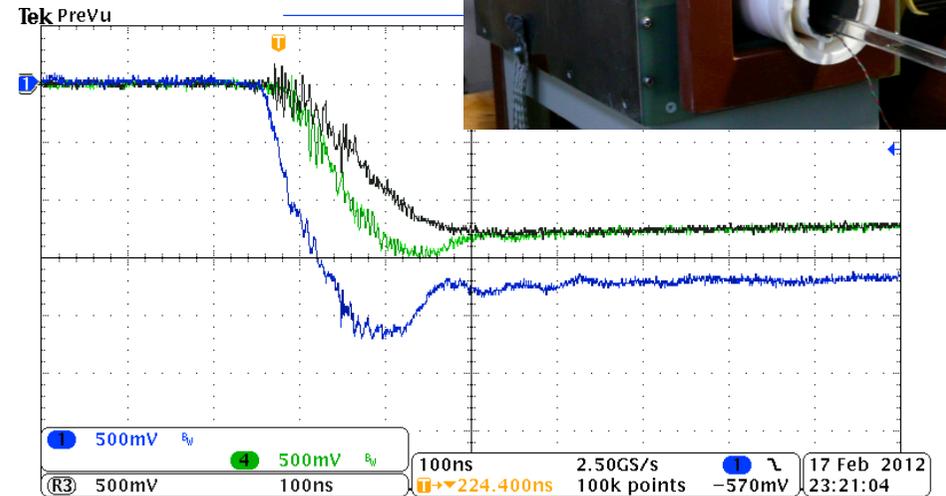
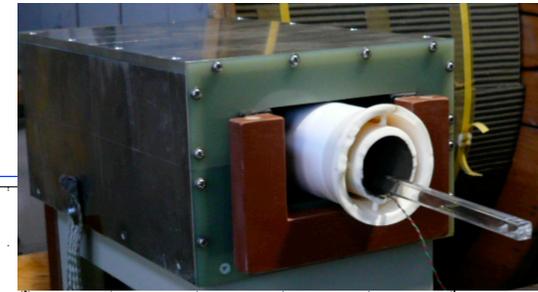
Magnetic Field Response and Chamber Temperature

Magnetic field response with Ti-coating ceramic chamber

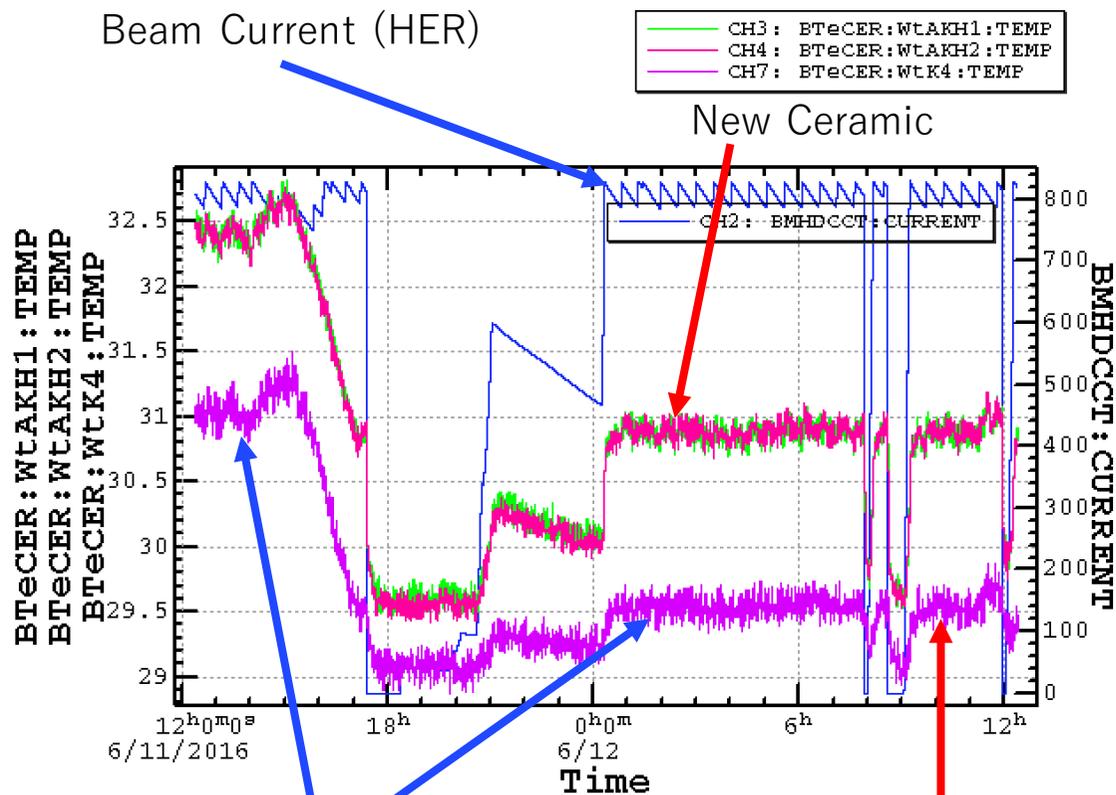


- : CT
- : Magnetic field with chamber
- : Magnetic field w/o chamber

- : CT
- : Magnetic field w/o chamber
- : Magnetic field with chamber



Temperature Rise(Cooling Water)



Same Beam Current
But different Temperature Rise
(1 Train 1576 Bunches)

Old Ceramic

	LER KEKB	HER KEKB	LER SKEKB	HER SKEKB
I max	1.6A	1A	3.6A	2.6A
# Bunch	1584	1584	2500	2500
ΔT	2.7	1.4	8.6	2.9 (8.6)
Power	0.56kW	0.29kW	1.8kW	0.6kW (1.8kW)

Abort Kicker: New Ceramic Chamber (Spattering)
Injection Kicker: used Ceramic Chamber (KEKB)

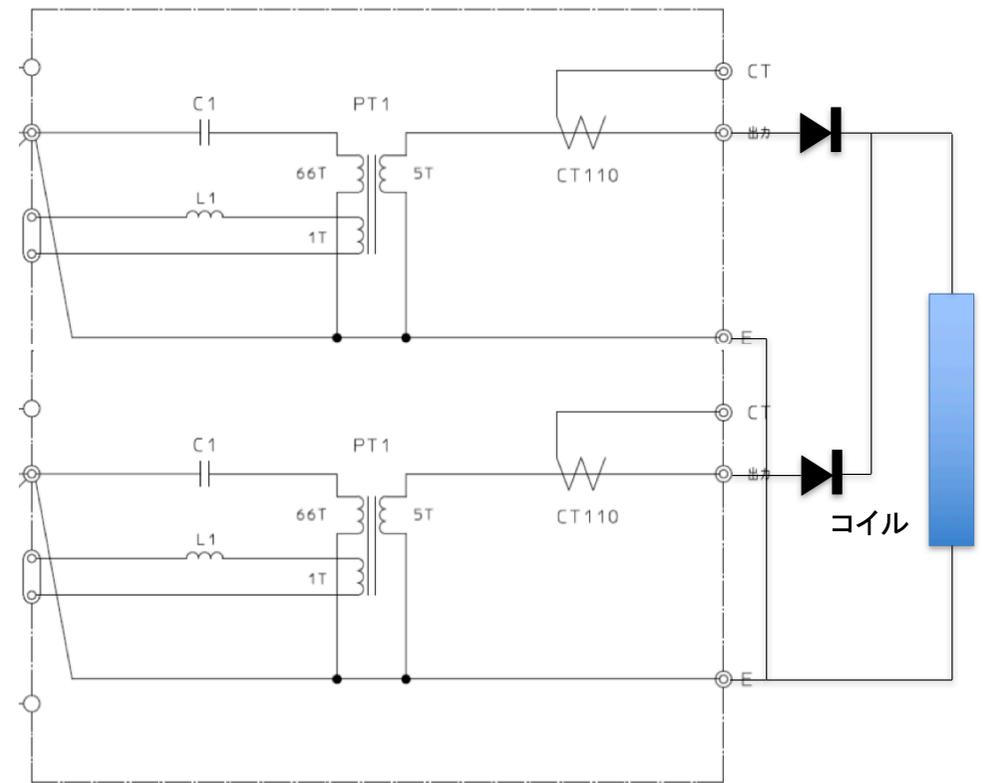
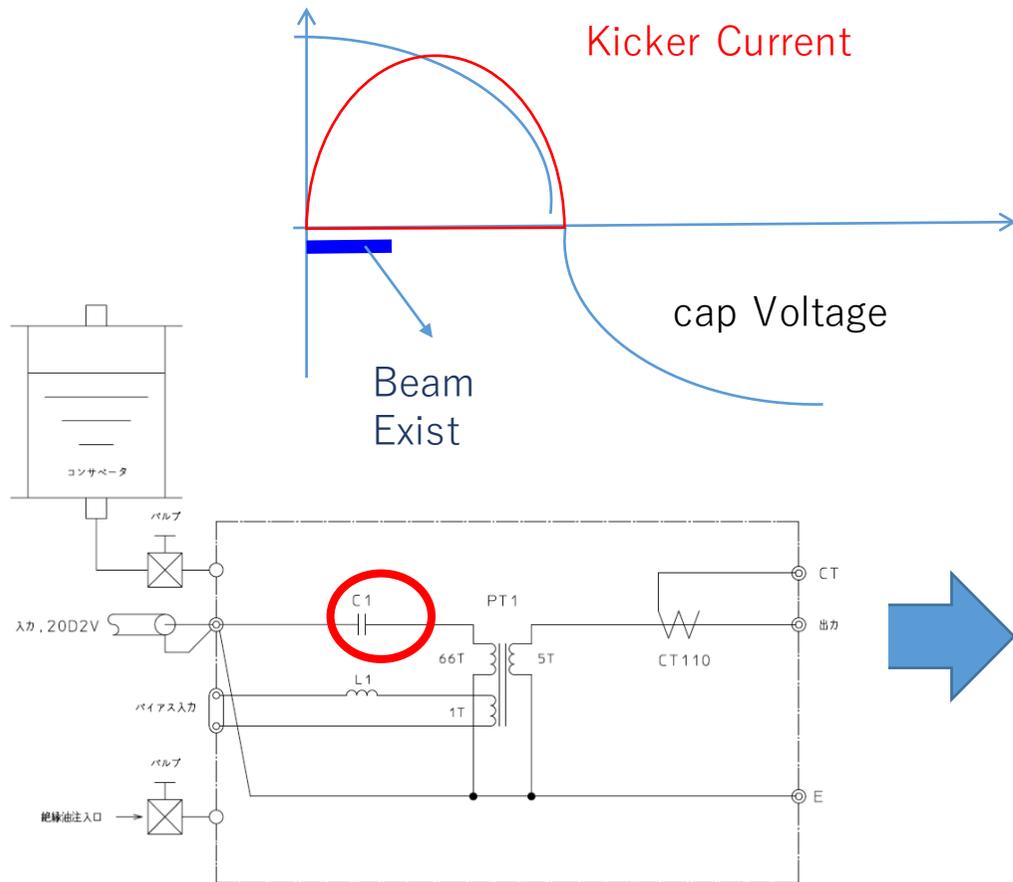
$$\Delta T(\text{New Chamber}) = 3 \times \Delta T(\text{Used Chamber})$$

Issues

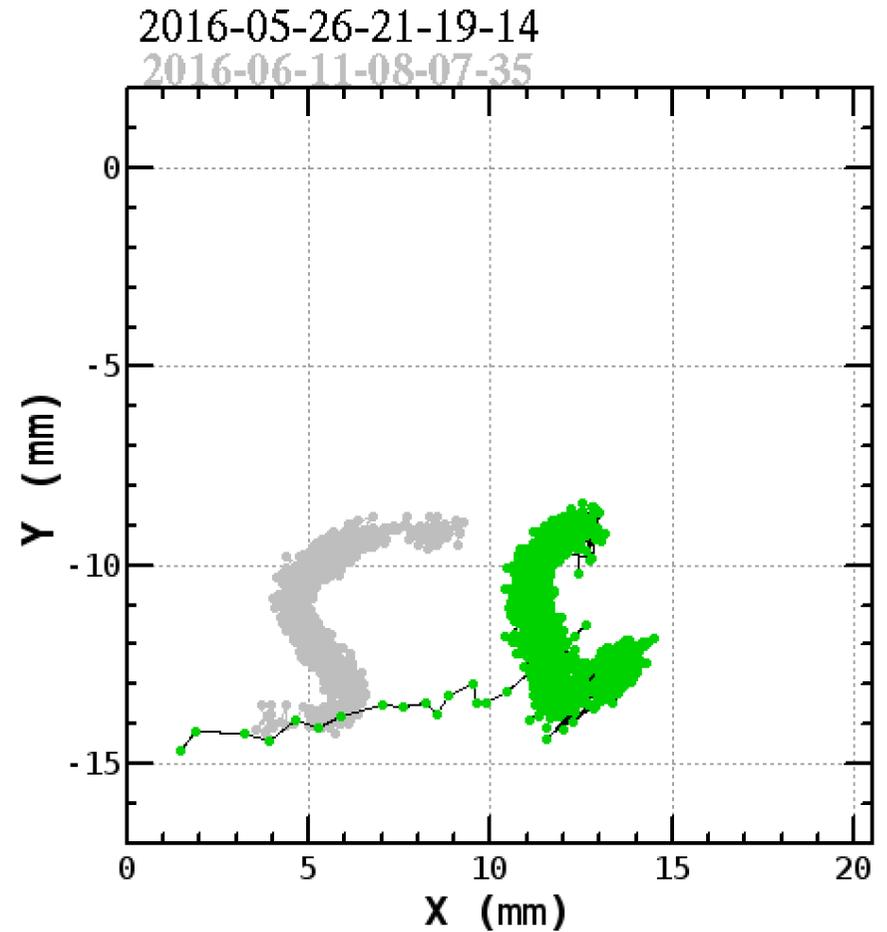
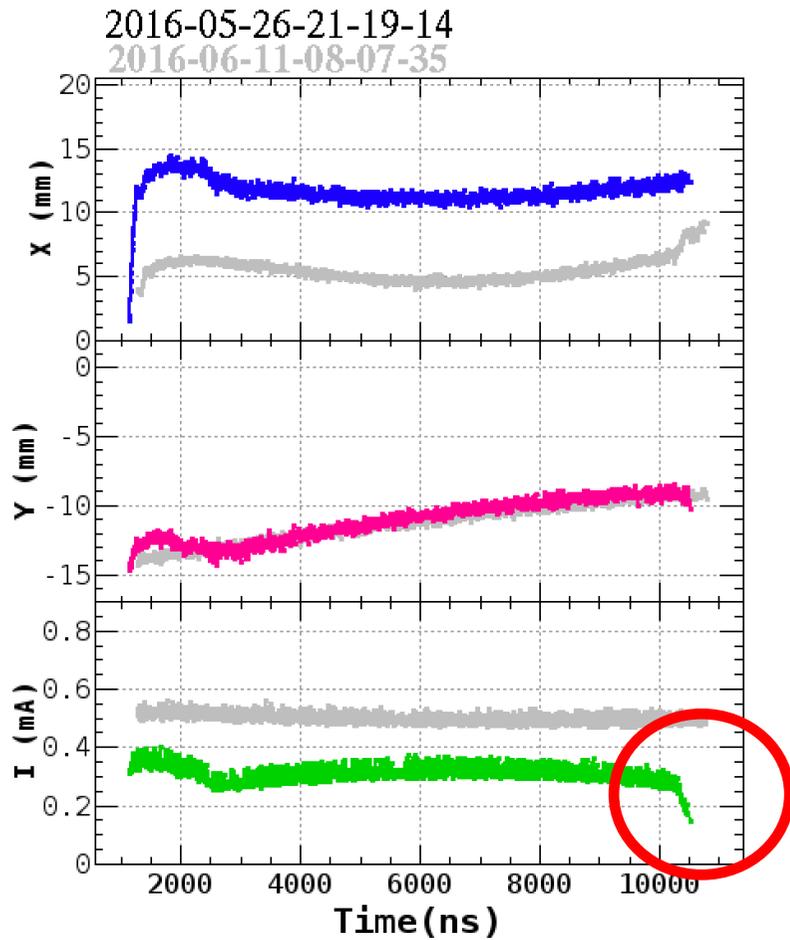
Abort System Failure possibility

Failure Events	What happen in the system	Damage
Thyratron Break Down	2% of Total Beam loss	No Damage
Gate circuit mulfunction	2% of Total Beam loss	No Damage
Thyratron misfire	Turn weak Bend magnets	No Damage
Gate circuit misfire	Turn weak Bend magnets	No Damage
H cap break down (charging)	Turn weak Bend magnets	No Damage
V cap break down (charging)	Turn weak Bend magnets	No Damage
Charger fault	Turn weak Bend magnets	No Damage
H cap break down (discharge)	Peak current will be low	Damage ?
H kicker Bias circuit fault	Turn weak Bend magnets	No Damage
H kicker Power Crober fault	Turn weak Bend magnets	No Damage
V kicker Cap Break Down (discharge)	No Vertical Sweep	Serious Damage
V kicker Bias circuit fault	No Vertical Sweep	Serious Damage

Vertical Kicker (Pulsed Transformer circuit)



Beam Loss at the end of train



Radiation Damage of diode of crowbar circuit

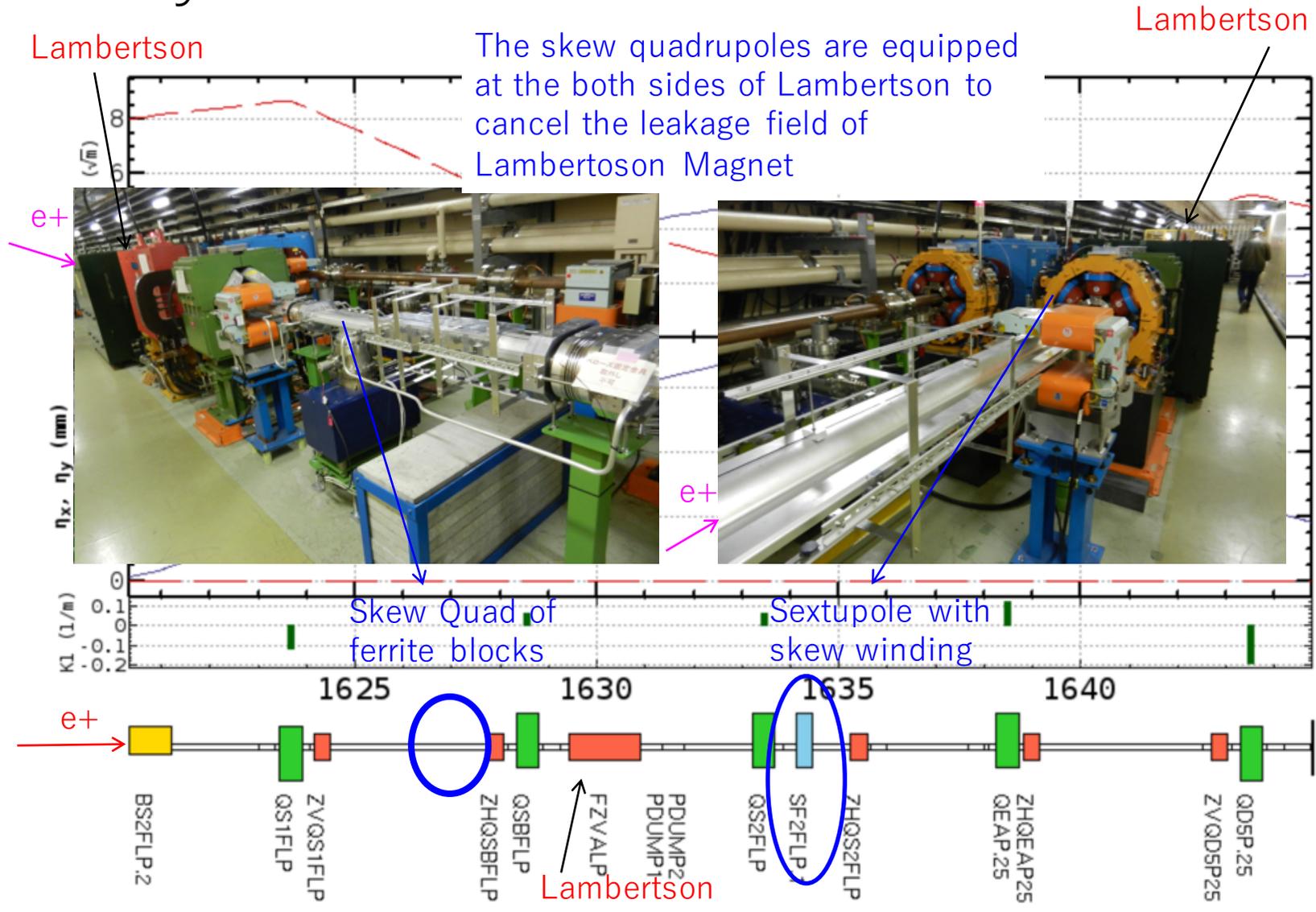
7mm Pb +200mm Polyechiren +1mm Pb
Reduce 1/10 radiation damage



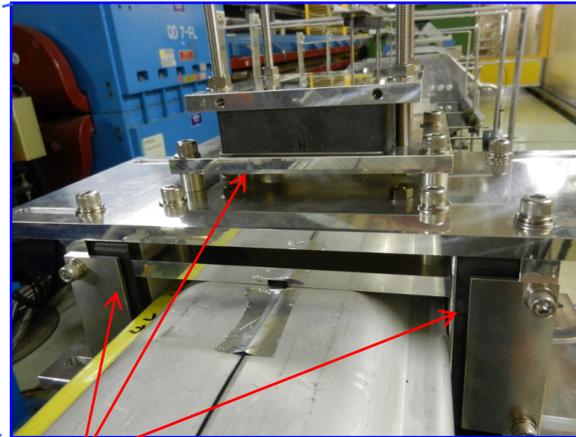
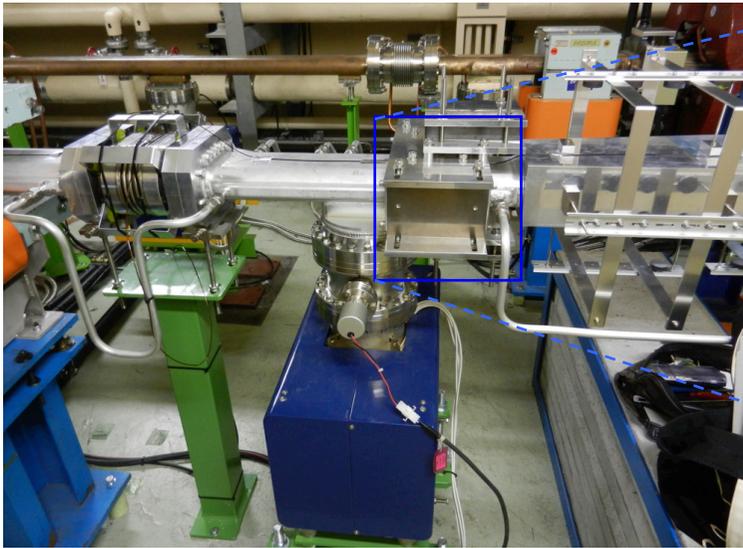
End

Backup

Layout around the Lambertson



The skew quadrupole permanent magnets to cancel the leakage field from the Lambertson



Ferrite block

Ferrite block

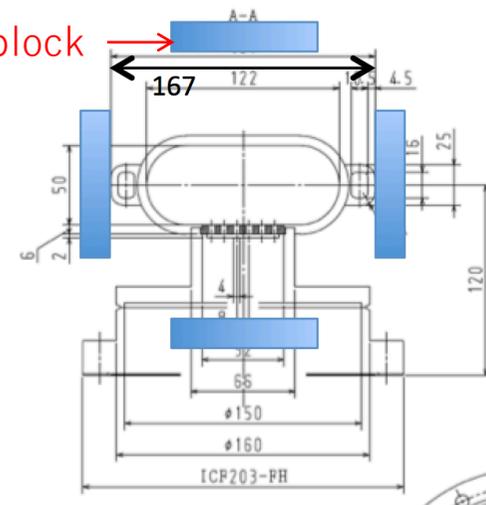
Size: 100 x 25.4 x 150 (mm)

$B \sim 550$ (Gauss)

$r = 85.5$ (mm)

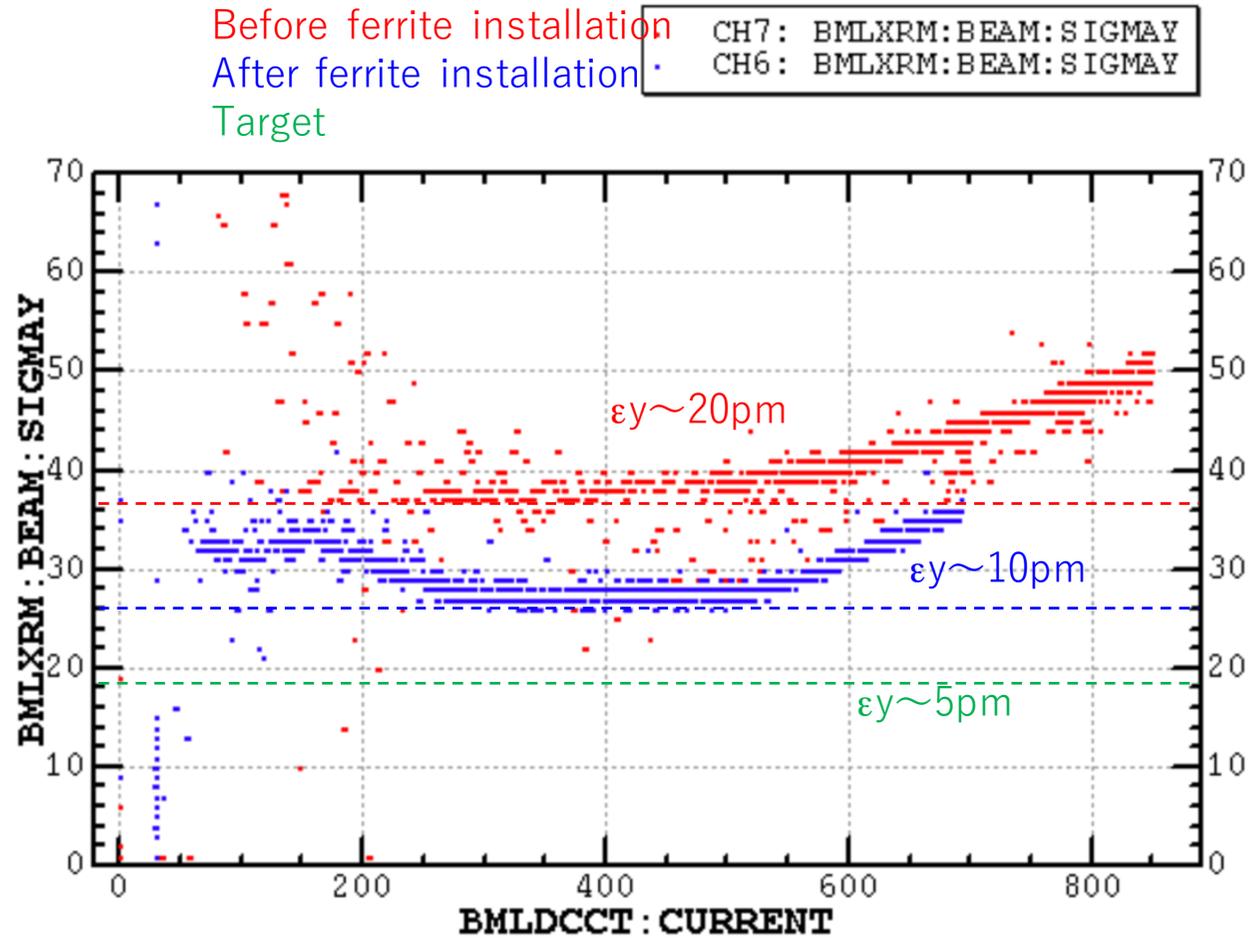
→ $SK1 = -7.7e-3$ (/m)

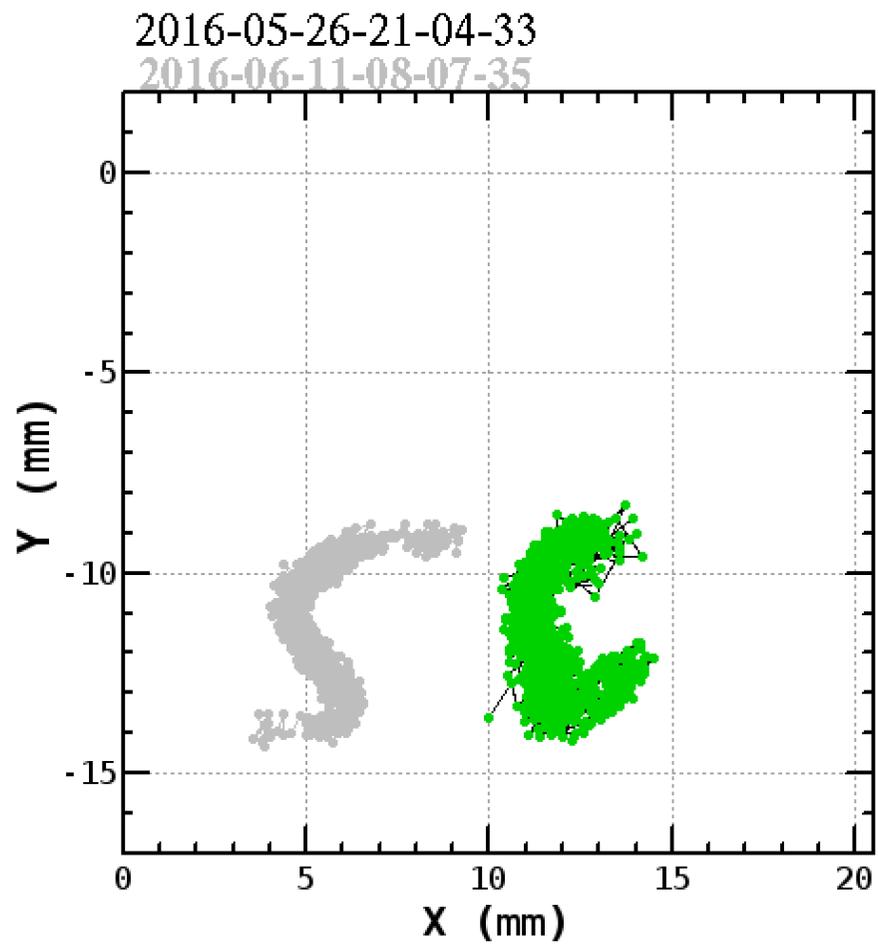
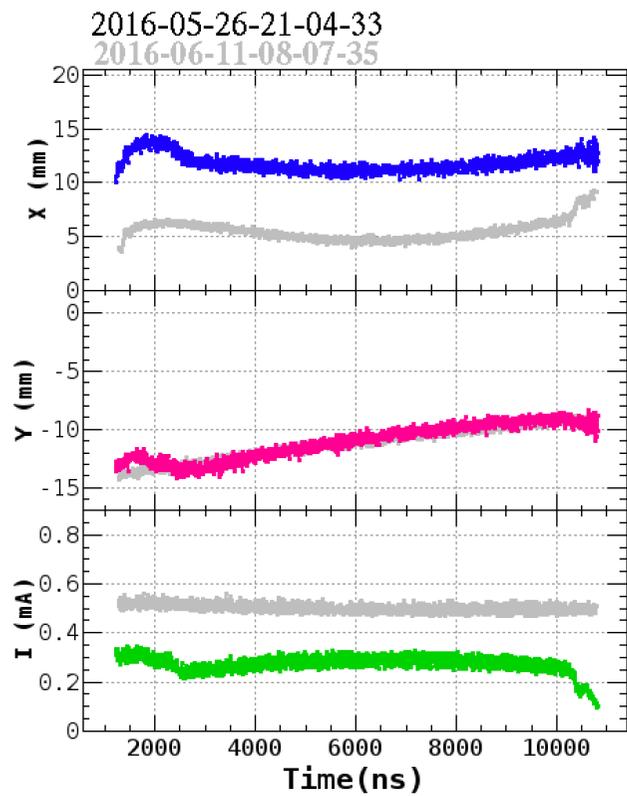
which is adjusted the requirement from optics.

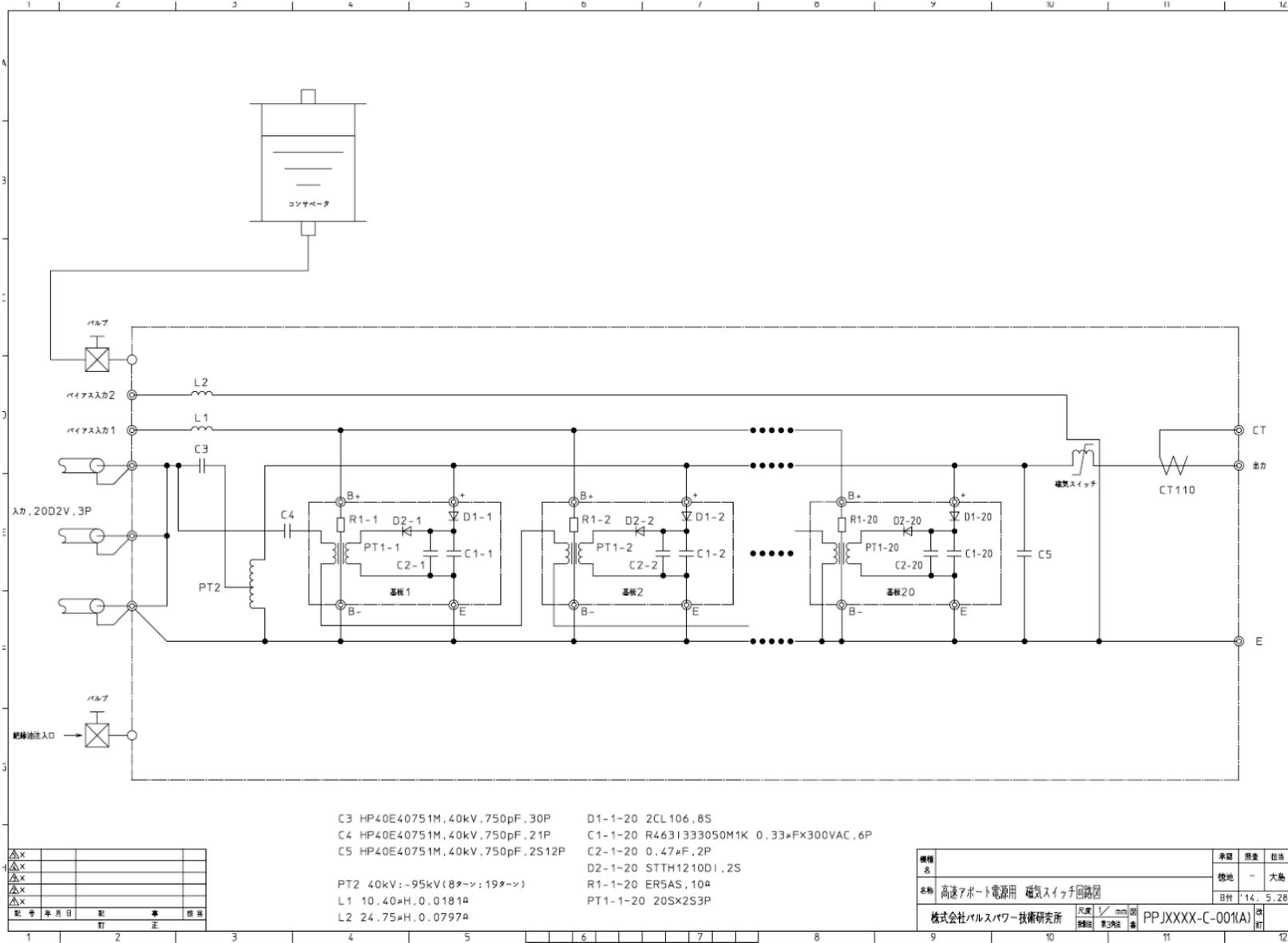


Vertical beam size measurement

Y. Ohnishi







- C3 HP40E40751M, 40kV, 750pF, 30P
- C4 HP40E40751M, 40kV, 750pF, 21P
- C5 HP40E40751M, 40kV, 750pF, 2S12P
- D1-1-20 2CL106, 8S
- C1-1-20 R4631333050M1K 0.33μFX300VAC, 6P
- C2-1-20 0.47μF, 2P
- D2-1-20 STH1210D1, 2S
- R1-1-20 ER5AS, 10μ
- PT1-1-20 20Sx2S3P
- PT2 40kV: -95kV (8ターン: 19ターン)
- L1 10.40μH, 0.0181A
- L2 24.75μH, 0.0797A

△x			
記号	年月日	記号	標準
		訂	正

機種名	承認	原案	担当
名称	徳地	-	大島
株式会社パルスパワー技術研究所		日付	14. 5. 28
図面	1/ mm	PPJXXXX-C-001(A)	訂